A new Radiation-hard Endoscope for Divertor Spectroscopy on JET

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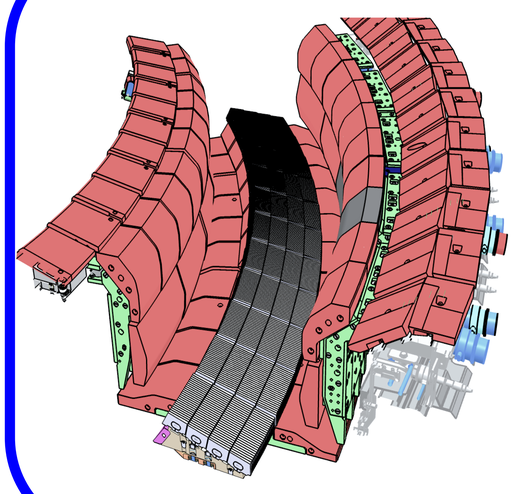
**See the Appendix of F. Romanelli et al., Proceedings of the 23rd IAEA Fusion Energy Conference 2010, Daejeon, Korea*

Overview



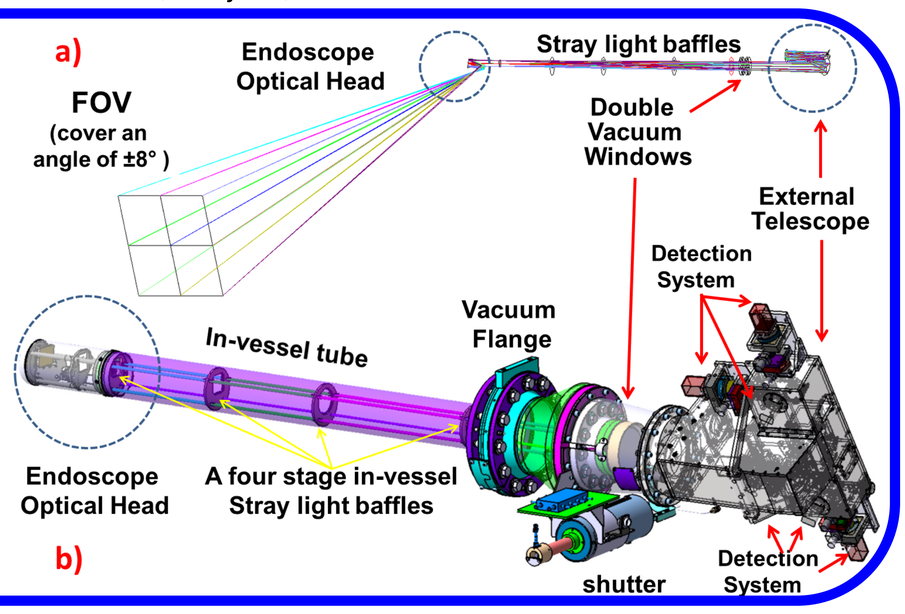
Main properties of the new endoscope:

- Full reflective optics (no chromatic aberration)
- high transmission from 390nm to 2500 nm
- No window in front of endoscope head
- Excellent spatial resolution, high MTF (resolution of single W lamellae at sufficient contrast)
- Relative calibration of transmission with new shutter design
- Rigid construction of in vessel components
- Tritium compatibility

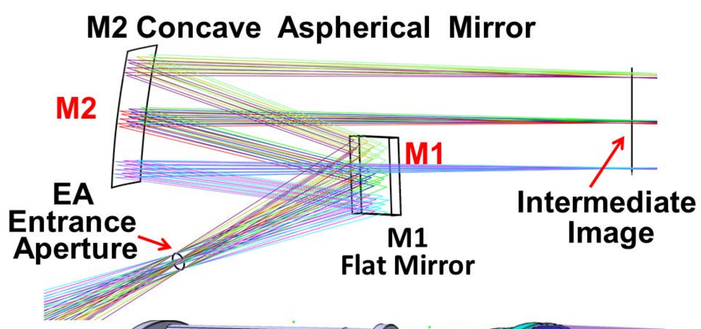
Optical design overview and mechanical layout

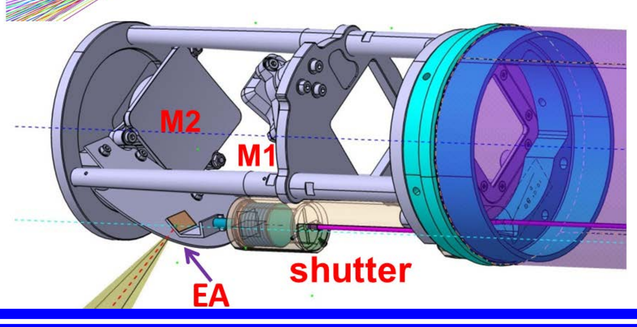
The optical system consists of two main components:

- the endoscope optical head with shutter actiator (in-vessel) and
- the external telescope optical assembly. (outside the vessel)



Endoscope Optical Head



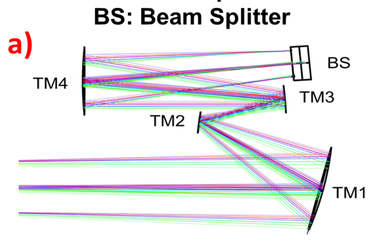


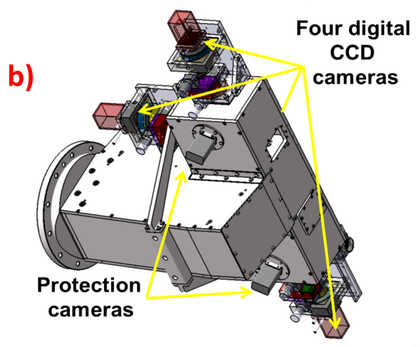
- Reflective optics only
- High Transmission due reduced number of the mirrors
- Mirror Surface quality better than λ/10
- **Endoscope optical Head:**
  - The two-mirror head design
  - Mirror M1 and M2 are off axis made from Al uncoated (single point diamond turning)
- **External Telescope:**
  - All mirrors TM1 – TM4, including the beam splitter BS, have been coated with Ag and a SiO_2 protection layer to enhance reflectivity especially in the VIS wavelength range.

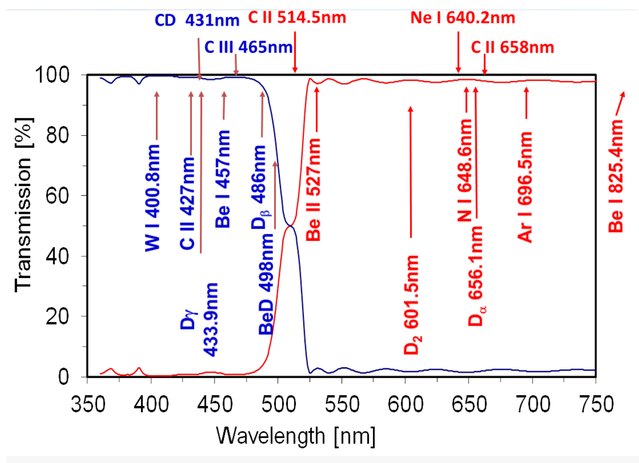
The optical design does not contain light beam obstructions in the in-vessel tube.

External Telescope

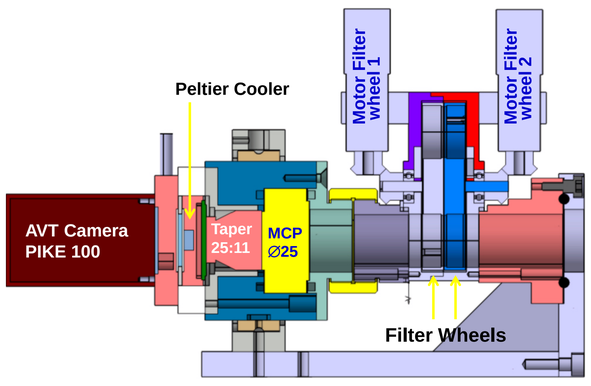
TM1-TM4: of axis aspherical mirrors
BS: Beam Splitter

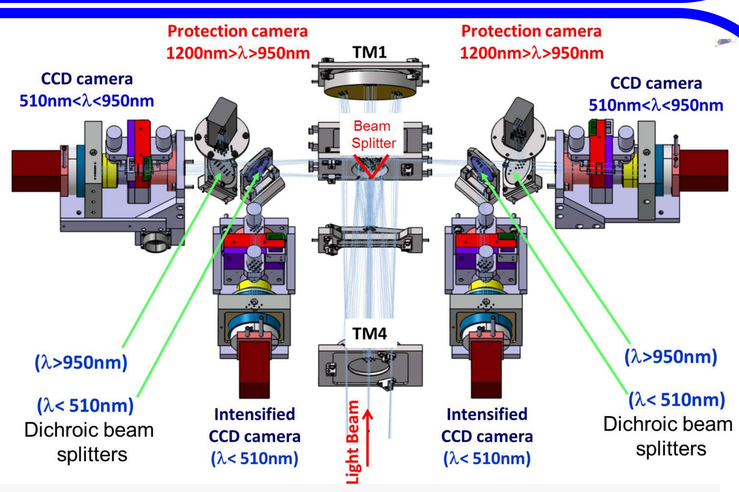






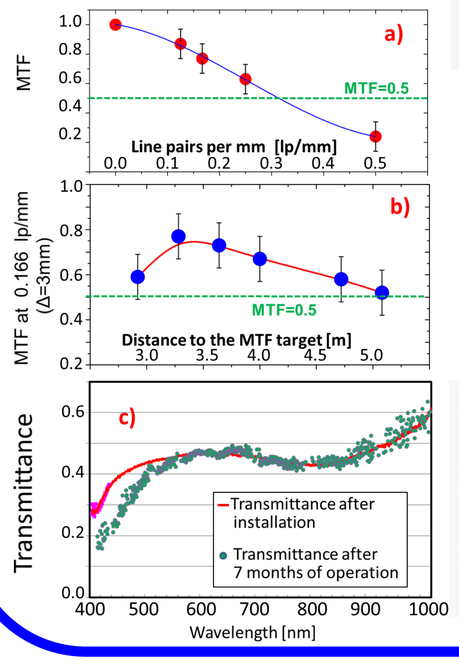
Detection System



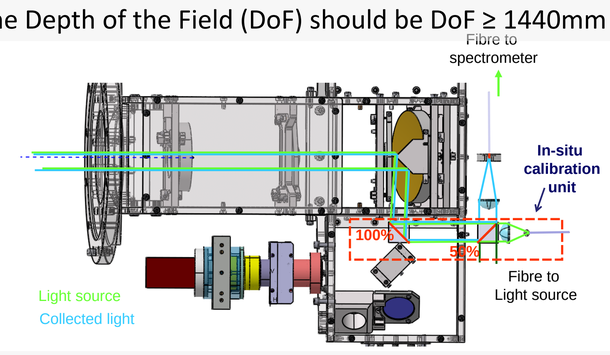


- Allied Vision Technologies (AVT) Pike F-100B CCD camera, 1MPixel, FireWire data connection via optical fibres, max. 33 fps at full resolution and 16 bits data output.
- The sensor is cooled by a thermoelectric Peltier module (-12C° with camera power switched on)
- Camera unit set:: 2 filter wheels for narrow band interference and neutral density filters ; fibre optic taper (magnification 25:11) to the CCD camera sensor
- Two of cameras are equipped with micro-channel plate (MCP) image intensifiers (Proxitronic BV2562BZ, photocathode Ø25 mm).

Performance

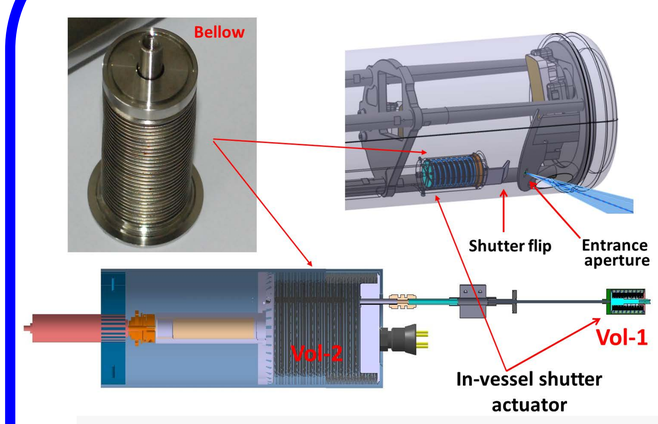


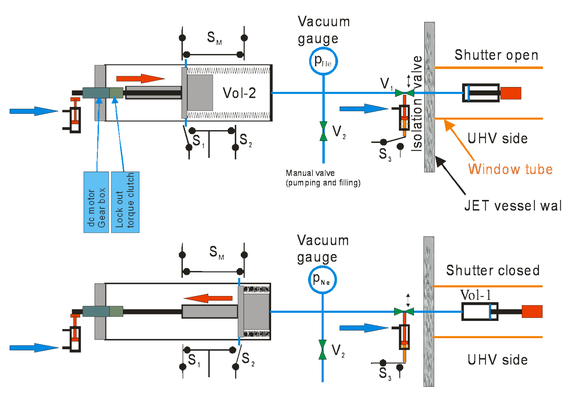
- The spatial resolution is better than 3mm at the object plane
- The Depth of the Field (DoF) should be DoF ≥ 1440mm



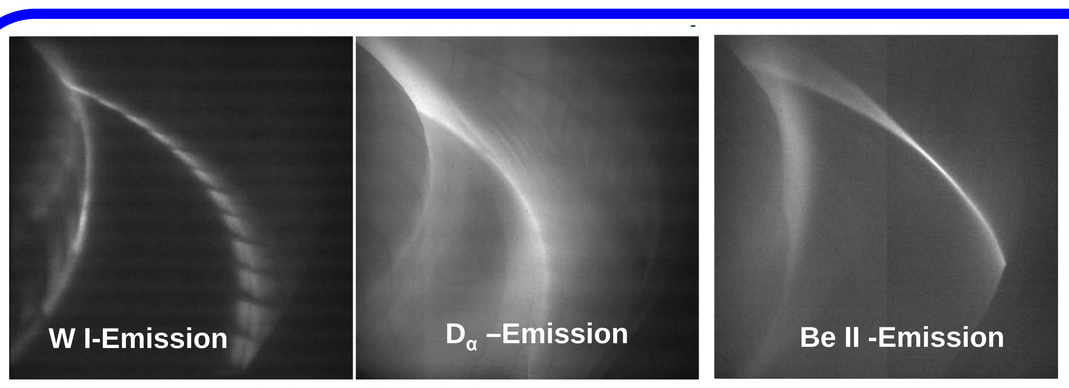
- Continuous tracing of possible transmittance degradation
- T ≥30% after installation the spectral range from 390 nm to 2500 nm.
- Some degradation of T for wavelengths λ< 500nm after 7 months of operation (Δ**T** ≈40% at 400 nm).

Shutter System Functionality





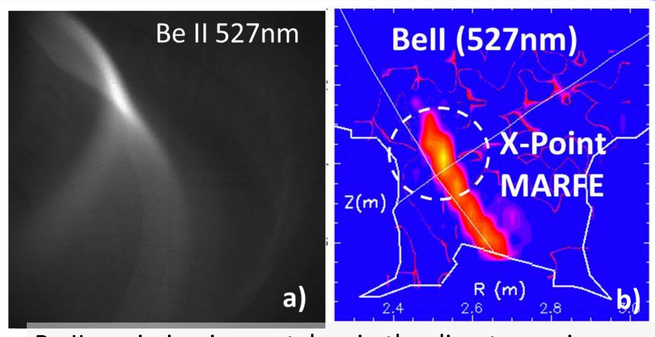
- Pneumatically operation
- Actuator stroke: 18mm
- Tested in vacuum and at 350°C (1000 cycles- 4 years of operation)
- The time response for shutter movement between open and close positions (and vice versa) is about 30 s



L-mode density limit discharge (B_T=2.4T, I_p=1.7 MA, P_{NBI}=2.0MW)

First Results with the Endoscope System

The image intensified camera which delivers the WI-emission profile was operated at the lowest MCP amplification and thus demonstrates the possibility to resolve the line radiation with respect to the optical transmittance in the UV range at 400nm.



Be II -emission image taken in the divertor region tomographic reconstructions of BeII-emission

Summary

- The KL11 endoscope was successfully installed in May 2011, more than 2 months before JET restart. The spatial resolution of the DES optical system delivered in the operating wavelength range from 390nm to 2500nm the expected optical performance: high optical transmittance (≥30% in the designed wavelength range) as well as a high spatial resolution that is ≤ 2 mm at the object plane and ≤ 3 mm for the depth of field (±0.7m).
- The new optical design includes options for the in-situ calibration of the endoscope transmittance during the experimental campaign, which allows the continuous tracing of possible transmittance degradation with time.
- A new type of ITER-like shutter system based on pneumatic techniques has been developed and integrated into the endoscope head.

Acknowledgements

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